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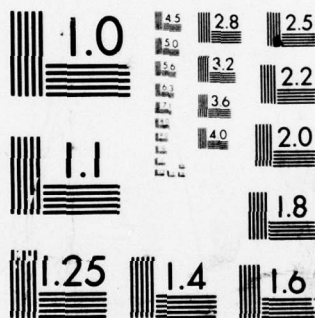
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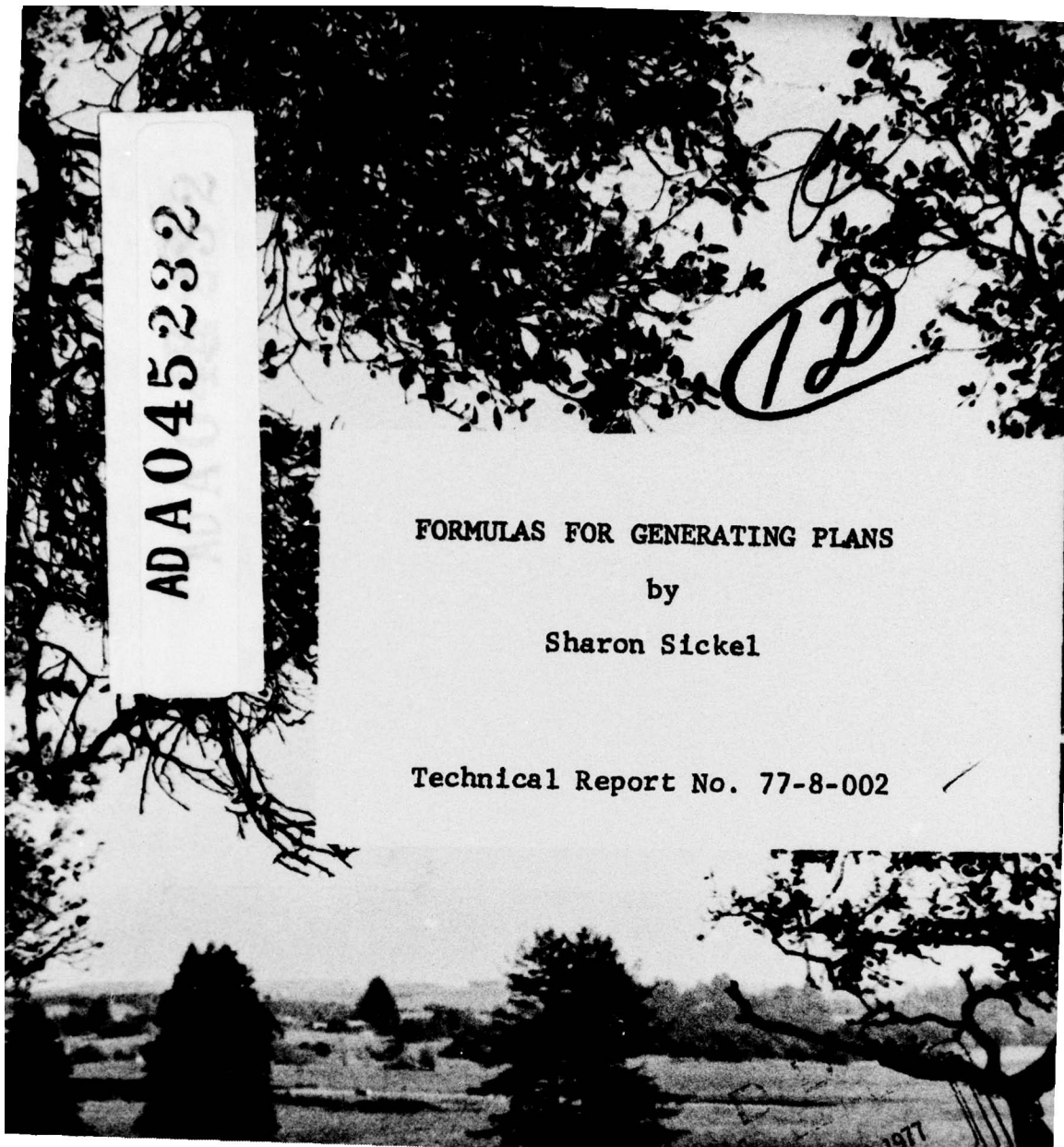
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FORMULAS FOR GENERATING PLANS

by

Sharon Sickel

Technical Report No. 77-8-002



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Formulas for Generating Plans

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It has been shown that any problem expressible as a theorem in the predicate calculus can be represented by a context-free attribute grammar such that the language of the grammar represents the plans that solve the problem.* A closed form for the language is often derivable; the notation for the closed form is a regular algebra -- an extension of regular expressions. Formal language theory can be used to simplify the grammar and the corresponding language.

Theorem proving has been used in the past for question answering and to generate or verify solutions to specific (ground case) problems. Here we generate algorithms. For example, solve $\text{factorial}(n)$ (rather than $\text{factorial}(6)$), or answer $\text{subset}(S,T)$ (rather than $\text{subset}(\{1, 2\}, \{0, 1, 2, 5\})$). The closed form derivable from the grammar mentioned above gives the control structure of the algorithm. There may be more than one closed

*Formal Grammars as Models of Logic Derivations, Sharon Sickel, submitted to IJCAI 77.

form that will accomplish the task, and we choose among them. In this way we avoid the complexity of having to describe all solutions, and instead choose one that lends itself to execution. The data manipulation of the steps of the algorithm is given by the unification of components of the problem specification. Specifically, assignment statements in the algorithm assign values to the variables that correspond to values the variables are unified with in the specification.

The closed form also provides information about certain properties of the algorithm. The domain and range of the task are derivable from the closed form by replacing terminal symbols by substitutions and performing an operation on them similar to composition. The closed form may also describe how to compute recursively defined functions iteratively by determining a priori when loops will terminate and by discovering an upper bound on the amount of information required at any one time. The original specification may inherently imply an algorithm containing redundancies. We may be able to automatically improve such algorithms. For example, if the zero function is described recursively, the implied computation is inefficient. However our analysis shows that the range consists of a single element. Therefore the algorithm for the function can be transformed to one that maps directly onto the single range element. Another example of this simplification occurs in generating plans for travel on a Manhattan grid with no barriers. To go from point $(0,0)$ to point (m,n) , we could do an arbitrarily large amount of meandering. However,

it is possible to derive a plan that will accomplish the trip in $m+n$ steps by using a less general closed form that nevertheless achieves the task for all m and n .

Some problems may be so hard that finding the closed forms directly from the grammar is not practical (or even possible). In these cases, we may be able to induce a general plan by solving the problem for a small set of elements of the domain and generalizing on those solutions. The generalization is guessed from the examples and must then be verified for the entire domain, usually by mathematical induction on the construction operator of the domain. If the domain is finite or recursively defined, this proof should be automatic.

The closed form used here provides an interface between formal specification of problems and the algorithms that solve them. The automatic generation of these forms is a step toward mechanized plan formation.

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